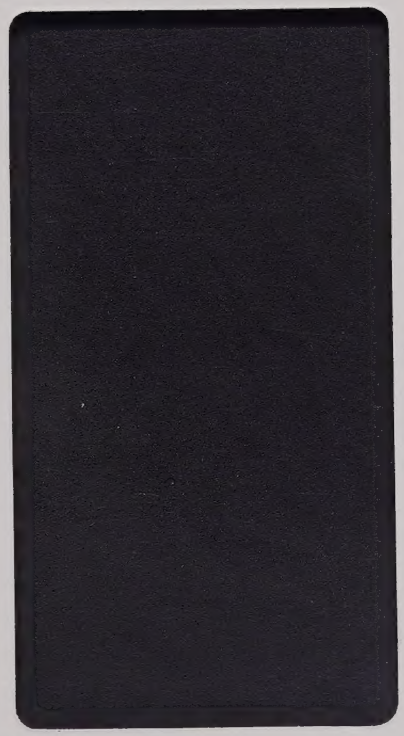
11188

INSTRUCTION MANUAL

# MODEL 410, 410C

MICRO-MICROAMMETER

KEITHLEY INSTRUMENTS



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## WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof (except tubes and batteries) which, within a year after shipment, proves defective upon examination. We will pay domestic surface freight costs.

To exercise this warranty, call your local field representative or the factory, DDD 216-795-2666. You will be given assistance and shipping instructions.

## REPAIRS AND RECALIBRATION

Keithley Instruments maintains a complete repair service and standards laboratory in Cleveland, and has an authorized field repair facility in Los Angeles.

To insure prompt repair or recalibration service, please contact your local field representative or the plant directly before returning the instrument.

Estimates for repairs, normal recalibrations, and calibrations traceable to the National Bureau of Standards are available upon request.

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# SECTION I INTRODUCTION

## Model 410

The Keithley Model 410 Micro-microammeter is a line operated vacuum tube electrometer designed and constructed especially for measuring small currents. Full scale ranges are from $10^{-3}$ to $3 \times 10^{-13}$ ampere.

The features include full-scale voltage drop at the input of less than five millivolts, zero drift of less than 2% of full scale in eight hours, good accuracy and calibration stability, and simplicity of operation. It also has an output which will drive a 0-1 to 0-5 milliampere recorder as well as the numerous potentiometer - rebalance recorders; one output terminal is at ground, making it convenient to connect cathode ray oscilloscopes or pen-driving amplifiers, similar to the Brush and Sanborn equipment.

The major panel controls are the range switch (amperes full-scale) and the zero. Minor controls are the Zero Check, used to short circuit the input and in setting the zero, Meter Polarity for providing up-scale readings for currents flowing in either direction and an ON - OFF power switch. The meter dial is illuminated, and these bulbs serve as the pilot light.

## Model 410C

The Keithley Model 410C is identical to the Model 410, except that the panel meter is provided with contacts which can be set to close at any predetermined meter pointer deflection. The delicate contacts of the meter operate a relay in the 410C, and the relay contacts (SPDT) are available for external switching functions through an AN connector on the rear of the chassis.

## Response Speed, both models

The 410 and 410C are shipped with capacitors shunting the range resistors on the $10^{-8}$ through $10^{-12}$ ampere ranges. The capacitors damp the response, limiting the amplification of spurious disturbances, and preventing overshoot and ringing when a square pulse of current is applied and input cable capacitance is as much as 5000 micro-microfarads. Such damping is usually preferred when long input cables are used, as with remote ion chambers. When maximum speed is desired, as in some production tests, and very short input cables are being used, the capacitors may simply be removed from the range switch. See details on page 2-2 .

## SECTION II DESCRIPTION

Twenty overlapping current ranges, from $10 \times 10^{-4}$ ampere to $3 \times 10^{-13}$ ampere are selected by the Amperes Full Scale switch, located left of the Meter. The accuracy of the ranges from $10 \times 10^{-4}$ through $10^{-8}$ is within 2%, $3 \times 10^{-9}$ through $3 \times 10^{-13}$ is within 4%.

Input Impedance is controlled by negative feedback from the output so that the voltage drop across the input terminals is less than 5 millivolts for full-scale meter deflection. This is based on proper zero setting; if the meter needle is not set at zero, with zero input current, about 3 millivolts constant potential per percent of full scale are added to the five millivolts.

The Input Connector is located on the back face of the chassis. It is a UHF connector with teflon insulation, and accepts a standard teflon insulated mating plug. The plug and lead wires or cable should be extremely well insulated to prevent the leakage of the small currents. A cap is provided for keeping dirt out when the instrument is stored.

Input Switch Labelled ZERO CHECK is located to the left of the Range Switch. When depressed, it effectively shorts the input to remove spurious charges, and provides the zero input current reference for zeroing the meter with the Zero Control.

Grid Current is less than $5 \times 10^{-14}$ ampere, and represents the limit of measurement of a vacuum tube electrometer. This is about 15% of full-scale on the most sensitive range.

Zero Drift, after a 30-minute warmup, is less than 2% of full scale per 24 hours on all ranges except $3 \times 10^{-13}$ ampere. On this range drift may be about 4%. Drift increases with source voltages below 300 millivolts.

Zero Control-The Zero knob is located to the right of the meter and is used for zeroing the meter with zero input current. Effectively zero input current can be obtained by depressing the Zero Check button. The input must not be short-circuited. This upsets the negative feedback path and makes it impossible to zero the meter.

It is recommended that the meter pointer not be set anywhere but zero on the meter scale with zero input current, because with the feedback used, a dc potential is developed across the input whenever the output and the panel meter are not zero for zero input current. Recorders, of course, can be biased to any part of their scale for zero volts at the Model 410 output.

Output is provided for driving recorders. The amplifier will develop 5 volts for full-scale meter deflection, and 5 milliamperes can be drawn without upsetting the circuits. The OUTPUT connector is at the rear of the chassis. The connection details and suitable output attenuators are discussed in OPERATION, Section III.

Response Speed of the 410 depends upon the current range being used and also upon the capacitance of the external circuitry. On the less sensitive ranges the speed is limited by the amplifier response, which is from dc to approximately 1,000 cps. On the ranges from $3 \times 10^{-8}$ to $10 \times 10^{-12}$ amperes the speed has been reduced to about 1.0 second by the addition of capacitors across the range resistors. On the three most sensitive ranges, shunt capacitance across the input limits the response speed. Because of the method of application of the negative feedback, the slowing effects of capacitance from the high input terminal to ground have been greatly reduced, but are still significant. Table I below gives typical response speeds; viz; the time constant of the response to a step function.

TABLE I

TYPICAL RESPONSE SPEEDS (to 63% of final current)

| Ranges, ampere | With no significant external capacitance (seconds) | With 5000 pf across the input (seconds) |
|---|---|---|
| $10 \times 10^{-13}$ | 3.5 | 8.7 |
| $10 \times 10^{-12}$ | 1.0 | 1.1 |
| $10 \times 10^{-11}$ | 0.5 | 0.7 |
| $10 \times 10^{-10}$ | 0.5 | 0.6 |
| $10 \times 10^{-9}$ | 0.4 | 0.5 |
| $10 \times 10^{-6}$ | 0.0005 | 0.0005 |

If the maximum speed of response is desired, the capacitors shunting the range resistors may be removed; however the increase response to spurious ac signals may interfere with recording, as mentioned in Section I.

Amplifier Noise (rms) is less than 1% of full scale, irrespective of the current range. From the most general point of view, grid current and amplifier zero drift are also background noise; these have already been discussed.

## Circuit Description

The circuit diagram DR 10867-C is enclosed at the back. The amplifier consists of two 5886 electrometer tubes operated as a balanced stage, with a substantial amount of in-phase rejection. Further in-phase rejection is obtained by supplying V1 and V2 screens from V3 and V4. A triode connected 6CM6 is used as the cathode follower output stage.

Negative feedback from the output (directly, or through a low impedance divider) is accomplished through the shunt resistor to the grid of the input electrometer tube. It is this feedback which keeps the input voltage drop low.

The open loop voltage gain of the amplifier, measured from the first stage grid to the feedback connection which would normally be connected to the low impedance end of the shunt resistor, is about 2500 on the less sensitive ranges, alternates between 1500 and 500 on the middle ranges, and is 150 on the $3 \times 10^{-13}$ ampere range. This assures a low input drop.

To insure low drift, the feedback-voltage (the voltage drop across the high resistance range resistors) is made large and alternates between 1.0 volt and 3.0 volts for most of the ranges. On the $10 \times 10^{-8}$ ampere range and those less sensitive it is 5.0 volts, while on the $3 \times 10^{-13}$ ampere range (the instrument's most sensitive) it is 0.3 volt. The alternation of the feedback voltage is used to economize on the very expensive high megohm resistors, so that only one is used for every decade of measured current. Table II, below, gives the value of $E_F$ and $R_S$ for each current range.

TABLE II

| Range Amperes Full Scale | $E_F$ volts | $R_S$ | Resistor Accuracy % |
|---|---|---|---|
| $10 \times 10^{-4}$ | 5 | 5K | 0.1 |
| $3 \times 10^{-4}$ | 5 | 16.67K | 1 |
| $10 \times 10^{-5}$ | 5 | 50K | 1 |
| $3 \times 10^{-5}$ | 5 | 166.7K | 1 |
| $10 \times 10^{-6}$ | 5 | 500K | 1 |
| $3 \times 10^{-6}$ | 5 | 1.667 Meg | 1 |
| $10 \times 10^{-7}$ | 5 | 5 Meg | 1 |
| $3 \times 10^{-7}$ | 5 | 16.67 Meg | 1 |
| $10 \times 10^{-8}$ | 5 | 50 Meg | 1 |
| $3 \times 10^{-8}$ | 3 | $10^8$ | 1 |
| $10 \times 10^{-9}$ | 1 | $10^8$ | 1 |
| $3 \times 10^{-9}$ | 3 | $10^9$ | 3 |
| $10 \times 10^{-10}$ | 1 | $10^9$ | 3 |
| $3 \times 10^{-10}$ | 3 | $10^{10}$ | 3 |
| $10 \times 10^{-11}$ | 1 | $10^{10}$ | 3 |
| $3 \times 10^{-11}$ | 3 | $10^{11}$ | 3 |
| $10 \times 10^{-12}$ | 1 | $10^{11}$ | 3 |
| $3 \times 10^{-12}$ | 3 | $10^{12}$ | 3 |
| $10 \times 10^{-13}$ | 1 | $10^{12}$ | 3 |
| $3 \times 10^{-13}$ | 0.3 | $10^{12}$ | 3 |

The power supply is regulated by a Sola transformer. Half-wave selenium rectifiers supply the B+ and B- potentials. The filtering is conventional.

Calibration is determined by the value of the high resistance range resistors and the value of the feedback resistors. From $10^{-3}$ to $10^{-8}$ amperes, the overall accuracy is better than 2%. From $3 \times 10^{-9}$ to $3 \times 10^{-13}$ amperes, the accuracy is better than 4%.

The meter is connected between the output terminal and ground. When the range resistor is shorted in zeroing the instrument, the meter measures the voltage existing between the input terminal and the output terminal (which are connected together when the shorting button is pressed) and ground.

The balancing of the amplifier, with the Zero control, is done in the filament circuit of V2. This is a convenient low-impedance point and does not disturb the electrode potentials of the low grid current electrometer tube.

## SECTION III OPERATION

Simplicity of operation is an outstanding characteristic of the Model 410. First connect the input to a current source, and the output to a recorder or external indicator, if desired.

Then: a) plug the power cord into a 110 volt 60 cps outlet. Note that because a Sola resonant regulating transformer is used, the power frequency, as well as voltage, must be the proper value.

b) Turn the amperes Full Scale to the $10 \times 10^{-4}$ position.

c) Turn the power switch to ON.

d) After a few minutes warmup, set the panel meter to zero with the ZERO control.

e) Advance the instrument's sensitivity with the range switch, until a usable deflection is obtained on the panel meter. The current is read directly. Attention should be paid to the METER polarity switch, so that an up-scale deflection is obtained.

f) Periodically check the zero setting by operating the ZERO CHECK switch and re-zeroing the meter if necessary.

### Input, using cabling

The current source should be connected to the input connector with the high impedance side of the current source associated with central conductor of the connector. The lead-in cable should be polyethylene, polystyrene, or teflon insulated coaxial cable, and the connector should have teflon insulation. Amphenol type 83-756 or equivalent is recommended. During preparation of cable and connectors, it is essential that all high impedance surfaces be kept scrupulously clean to avoid leakage. With graphite coated cable, it is necessary to avoid tracking graphite onto the high impedance surfaces of the cut end of the insulation and the teflon surface of the connector. Movement of the cable during measurement should be avoided since this will cause spurious needle movements, because of capacitance changes and generation of static charges.

GRID CURRENT in the Model 410 is less than $5 \times 10^{-14}$ ampere - usually about $2 \times 10^{-14}$ ampere. It can be read directly on the $3 \times 10^{-13}$ ampere range after carefully shielding the high impedance input conductor such as by screwing the connector cap on.

The grid current can be subtracted algebraically from the total current read on the meter to give the correct current in the circuit being measured on the most sensitive ranges.

RECORDING: The Keithley Model 370 Recorder is ideally suited for recording with the Model 410. The Model 370 has one milliampere full-scale sensitivity, 1/2-second rise time, 10 chart speeds and 1% linearity. It does not degrade the performance of the Model 410, even in the most critical applications.

The Model 370 is easy to use with the Model 410. To use the Model 370 with the Model 410, connect the two instruments with the Model 3701 Input Cable and adjust the Recorder for full-scale deflection by adjusting the Calibration Control on the Model 370. The Model 3701 Cable is furnished with the Model 370. The cable has an Amphenol 80-PC2F which mates directly with the output connector on the Model 410.

The Model 410 has an output for full-scale meter deflection of ±5 volts at up to 5 milliampere. This output can, therefore, be used to drive either a 1 milliampere recorder, like the Model 370, or a 5 milliampere recorder. When driving a 5 milliampere recorder attach a resistor in series between the Model 410 and the recorder, to make the recorder full-scale deflection equal the panel meter full-scale deflection. The value of this series resistor should be between 920 and 940 ohms. The exact series resistance varies from recorder to recorder, and a portion of the series resistance should be adjustable so that the recorder may be calibrated exactly against the panel meter.

The Speed of Response, or the time constant of an input transducer and micro-microammeter, depends upon the speed of response of the circuitry of the instrument and also upon the capacitance of the current source and its connecting cable. Because of the way the negative feedback is applied in the Model 410, the external input capacitance is not nearly as important as in systems using a voltmeter across a shunting resistor, and quite large capacitances can be tolerated without having an impossibly slow response. Thus, a cable run from an ion chamber to the micro-microammeter is permissible.

The internal time constant of the Model 410 depends upon both the frequency response of the amplifier stages and the time constants of the high megohm resistors and the associated distributed capacitances. These change from range to range on the 410, the speed decreasing as the sensitivity is increased. Table I in Section II, Description, gives quantitative values.

+216 Volts. A connector has been mounted on the back face of the chassis to provide +216 volts for polarizing an ion chamber. The potential is derived from 2 OB2 voltage regulator tubes, and is well filtered. The supply can be short circuited without damaging it. The chassis connector is Cinch-Jones S101, and P101 is the mating plug.

# SECTION IV MAINTENANCE

The Keithley Model 410 Micro-microammeter has been designed to give long, trouble-free service. High quality components have been used throughout, and the circuits are stabilized by a substantial amount of negative feedback.

DR 10867-C, at the back, is the detailed circuit schematic diagram of the Model 410. The circuit operation was discussed in Section II, Description.

## Maintenance Adjustments

One maintenance control is provided. It is accessible from the top of the chassis, and is located behind the meter.

R138, METER CALIBRATION, is in series with the Meter. To recalibrate, use the $10 \times 10^{-4}$ range and, with $7 \times 10^{-4}$ ampere through the input circuit, adjust R138 so the meter reads exactly 7.0. Since the shunt resistor on this range is accurate to 0.1% of its nominal value the overall accuracy can be adjusted to about 1% of full scale. On the $3 \times 10^{-4}$ to $10 \times 10^{-9}$ ampere range the range resistors are accurate to 1% and, providing the calibration was accurately done on the $10 \times 10^{-4}$ range, the overall accuracy will be 2%. From $3 \times 10^{-9}$ to $3 \times 10^{-13}$ amperes the range resistors are accurate to 3% and the overall accuracy will be 4%.

Vacuum Tubes V1 and V2 are the two electrometer tubes, and are located in an aluminum can which plugs onto the top of the chassis near the input terminals. The tubes have been selected, matched and labeled: V1 and V2 are Keithley part EV5886-8. It is recommended that the complete Input Tube Assembly, Model 4102, be kept for replacement purposes.

The other tubes are standard receiving tubes and need no special selection to assure satisfactory performance of the Model 410.

INSULATION: All insulation for the high impedance conductors is made of teflon, as are the contact insulators on the range switch. This should give satisfactory service in all humidities. Occasionally, the high impedance insulators should be inspected to insure that they are free from dirt and dust.

CONNECTOR CAP: The cap for the input connector should be kept in place whenever the connector is not being used. In storage and in transport, it keeps the insulation from accumulating dust and dirt. Before screwing the cap back onto the connector, be certain that it is clean, so the insulation will not be contaminated.

## SECTION V SPECIAL INSTRUCTIONS FOR THE MODEL 410C

DR 11165-C is the circuit schematic diagram of the Model 410C. It differs from the 410 in providing the meter contacts, and the relay which is controlled by them.

The meter-relay is manufactured by Assembly Products, Inc., of Chesterland, Ohio, Model 461-C. Its contacts will close when the black meter pointer coincides with the red index pointer. The index can be set easily to any point on the meter scale by rotating the black knob on the front of the meter.

To obtain reliable contacting of the meter, the contacts are locked together electrically. Unlocking can be accomplished by operating the RESET button on the panel, or by a remote switch.

To complete the locking path, it is necessary that contacts A and B of the AN connector be connected. This can be done within the mating male plug, if resetting is to be done only with the panel button, or leads can be run to a remote reset relay or switch.

The one AN connector, it will be seen on the schematic diagram, is used for the resetting circuit, control relay contacts, and the output to a recorder.

The relay contacts are rated 5 amperes at 110 volts AC, or 24 volts DC.

## SECTION 6. REPLACEABLE PARTS

6-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Models 410 and 410C. The List gives the circuit designation, the part description, a suggested manufacturer, manufacturer's part number and the Keithley Part Number. The name and address of the manufacturers listed in the "Mfg. Code" column are contained in Table 5.

6-2. HOW TO ORDER PARTS.

a. For parts orders, include the instrument's model and serial number, the Keithley Part Number, the circuit designation and a description of the part. All structural parts and those parts coded for Keithley manufacture (80164) must be ordered from Keithley Instruments, Inc. In ordering a part not listed in the Replaceable Parts List, completely describe the part, its function and its location.

b. Order parts through your nearest Keithley distributor or the Sales Service Department, Keithley Instruments, Inc.

c. Parts marked with (i) are contained in the Model 4102 Input Can. Replace these components as a complete assembly with the plug-in can.

| | | | |
|---|---|---|---|
| amp | ampere | m | milli ($10^{-3}$) |
| | | Mfg. | Manufacturer |
| CerD | Ceramic, Disc | Mil. No. | Military Type Number |
| Comp | Composition | | |
| | | Ω | ohm |
| DCb | Deposited Carbon | | |
| | | Poly | Polystyrene |
| ETB | Electrolytic, tubular | p | pico ($10^{-12}$) |
| f | farad | μ | micro ($10^{-6}$) |
| GDCb | Glass Enclosed Deposited Carbon | v | volt |
| | | Var | Variable |
| k | kilo ($10^{3}$) | | |
| | | w | watt |
| M or meg | mega ($10^{6}$) or megohms | WW | Wirewound |
| | | WWVar | Wirewound Variable |

TABLE 4. Abbreviations and Symbols.

## MODELS 410, 410C REPLACEABLE PARTS LIST

(Refer to Schematic Diagram 10867D for Model 410 circuit designations, to 11165D for Model 410C.)

### CAPACITORS

| Circuit Desig. | Value | Rating | Type | Mfg. Code | Mfg. Part No. | Keithley Part No. |
|---|---|---|---|---|---|---|
| C101 | 5000 pf | 500 v | Poly | 71590 | CPR-5000J | C138-5000P |
| C102 | 510 pf | 500 v | Poly | 71590 | CPR-510J | C138-510P |
| C103 | 47 pf | 500 v | Poly | 71590 | CPR-47J | C138-47P |
| C104 | 5 pf | 200 v | Poly | 14167 | E1013-1 | C31-5P |
| C105 | .02 µf | 1000 v | CerD | 72982 | 841Z5V203P | C22-.02M |
| C106 | 100 pf | 1000 v | CerD | 72982 | 831X5R101K | C22-100P |
| C107 (i) | 100 pf | 1000 v | CerD | 72982 | 831X5R101K | C22-100P |
| C401 | 40 µf | 250 v | ETB | 56289 | TVA1511 | C27-40M |
| C402 | 150 µf | 150 v | ETB | 56289 | TVA1422 | C9-150M |
| C403 | 40 µf | 250 v | ETB | 56289 | TVA1511 | C27-40M |
| C404 | 150 µf | 150 v | ETB | 56289 | TVA1422 | C9-150M |
| C405 | 40 µf | 250 v | ETB | 56289 | TVA1511 | C27-40M |
| C406 | 20 µf | 450 v | ETB | 56289 | TVA1709 | C8-20M |
| C407 | .02 µf | 1000 v | CerD | 72982 | 841Z5V203P | C22-.02M |
| C408 | 1.0 µf | Supplied with TR-17. | | | | |

### DIODES

| Circuit Desig. | Type | Number | Mfg. Code | Keithley Part No. |
|---|---|---|---|---|
| D101 | Selenium | PT065 | 81483 | RF-18 |
| D102 | Selenium | PT065 | 81483 | RF-18 |
| D103 | Selenium | PT065 | 81483 | RF-18 |
| D104 | Selenium | PT065 | 81483 | RF-18 |
| D105 | Selenium | PT065 | 81483 | RF-18 |
| D106 | Selenium | PT065 | 81483 | RF-18 |
| D107 (c) | Selenium Bridge | C1B | 81483 | RF-7 |

### MISCELLANEOUS PARTS

| Circuit Desig. | Description | Mfg. Code | Keithley Part No. |
|---|---|---|---|
| DS-1 | Meter Lamp (Mfg. No. 313) | 08804 | PL-1 |
| F-1 | Fuse, slow blow, 1.5 amp, 3 AG (Mfg. No. 31301.5) | 75915 | FU-8 |
| -- | Fuse Holder (Mfg. No. 342012) | 75915 | FH-3 |

(i) Part contained in Model 4102 Input Can.
(c) Used only on Model 410C.

MISCELLANEOUS PARTS (Cont'd)

| Circuit Desig. | Description | Mfg. Code | Keithley Part No. |
|---|---|---|---|
| J1 | Receptacle, uhf, INPUT, Mil. No. SO-239A (Mfg. No. 6804) | 91737 | CS-64 |
| -- | Reducing Adapter, uhf, Mil. No. UG-175/U (Mfg. No. 83-185) | 02660 | CS-36 |
| -- | Plug, uhf, Mate of J1, Mil. No. 49190 (Mfg. No. 83-822) | 02660 | CS-49 |
| -- | Dust Cap, Mil. No. MX-913/U (Mfg. No. M913) | 91737 | CAP-4 |
| J2(a) | Receptacle, Microphone, OUTPUT (Mfg. No. 80-PC2F) | 02660 | CS-32 |
| --(a) | Plug, Microphone, Mate of J2 (Mfg. No. 80-MC2M) | 02660 | CS-33 |
| J2(c) | Receptacle, OUTPUT (Mfg. No. MS3102A-18-1S) | 02660 | CS-23 |
| J3 | Receptacle, Microphone, +216 V (Mfg. No. 80-C) | 02660 | CS-34 |
| -- | Plug, Microphone, Mate of J3 (Mfg. No. 80-M) | 02660 | CS-35 |
| K1(c) | Relay | 80164 | RL-3 |
| M1(a) | Meter | 80164 | ME-6 |
| M1(c) | Meter | 80164 | ME-6C |
| P1 | Cord Set, 6 ft. (Mfg. No. 4638-13) | 93656 | CO-5 |
| -- | Cable Clamp | 80164 | CC-4 |
| P2(c) | Plug, Mate of J2 (Mfg. No. MS3106A-18-1P) | 02660 | CS-22 |
| S1 | Rotary Switch less components, AMPERES FULL SCALE | 80164 | SW-137 |
| -- | Rotary Switch with components, Amperes Full Scale | 80164 | 15191B |
| -- | Skirted Knob, Amperes Switch | 80164 | KN-8 |
| S2 | Push Button Assembly, ZERO CHECK | 80164 | 14131B |
| S3 | Toggle Switch, DPDT, METER (Mfg. No. 20905-FR) | 04009 | SW-14 |
| S4 | Toggle Switch, DPDT, ON-OFF (Mfg. No. 20905-FR) | 04009 | SW-14 |
| -- | Skirted Knob, Zero Control | 80164 | KN-8 |
| S5(c) | Push Button Switch, RESET | 80164 | SW-35 |
| T1 | Transformer | 80164 | TR-17 |

(a) Used only on Model 410.
(c) Used only on Model 410C.

RESISTORS

| Circuit Desig. | Value | Rating | Type | Mfg. Code | Mfg. Part No. | Keithley Part No. |
|---|---|---|---|---|---|---|
| R101 | 5 kΩ | 1%, 1/2 w | WW | 11502 | WW8J | R18-16-5K |
| R102 | 16.67 kΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-16.67K |
| R103 | 50 kΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-50K |
| R104 | 166.7 kΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-166.7K |
| R105 | 500 kΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-500K |
| R106 | 1.667 MΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-1.667M |
| R107 | 5 MΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-5M |
| R108 | 16.67 MΩ | 1%, 1 w | DCb | 91637 | DC-1 | R13-16.67M |
| R109 | 50 MΩ | 1%, 2 w | DCb | 91637 | DC-2 | R14-50M |
| R110 | 100 MΩ | 1%, 2 w | DCb | 91637 | DC-2 | R14-100M |
| R111 | $10^9$ Ω | +3%, -0% | GDCb | 63060 | RX-15 | R20-$10^9$ |
| R112 | $10^{10}$ Ω | +3%, -0% | GDCb | 63060 | RX-15 | R20-$10^{10}$ |
| R113 | $10^{11}$ Ω | +3%, -0% | GDCb | 63060 | RX-15 | R20-$10^{11}$ |
| R114 | $10^{12}$ Ω | +3%, -0% | GDCb | 63060 | RX-15 | R20-$10^{12}$ |
| R115 | 2 kΩ | 1%, 1/4 w | WW | 11502 | WW10J | R18-15-2K |
| R116 | 2 kΩ | 1%, 1/4 w | WW | 11502 | WW10J | R18-15-2K |
| R117 | 700 Ω | 1%, 1/4 w | WW | 11502 | WW10J | R18-15-700 |
| R118 | 300 Ω | 1%, 1/4 w | WW | 11502 | WW10J | R18-15-300 |
| R119(i) | 22 MΩ | 10%, 1/2 w | Comp | 01121 | EB | R1-22M |
| R120(i) | 10 MΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-10M |
| R121(i) | 10 MΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-10M |
| R122 | 200 Ω | 3%, 5 w | WWVar | 73138 | A | RP4-200 |
| R123 | 12.5 kΩ | 3%, 7 w | WW | 91637 | RLS-7 | R7-12.5K |
| R124 | 12.5 kΩ | 3%, 7 w | WW | 91637 | RLS-7 | R7-12.5K |
| R125 | 100 kΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-100K |
| R126 | 250 Ω | 1%, 1/4 w | WW | 11502 | WW10J | R18-6-250 |
| R127 | 150 Ω | 1%, 1/4 w | WW | 11502 | WW10J | R18-6-150 |
| R128 | 20 kΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-20K |
| R129 | 10 kΩ | 1%, 5 w | WW | 91637 | RS-5 | R4-10K |
| R130 | 1 MΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-1M |
| R131 | 60 kΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-60K |
| R132 | 1 MΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-1M |
| R133 | 5 MΩ | 1%, 1/2 w | DCb | 79727 | CFE-15 | R12-5M |
| R134 | 8 MΩ | 1%, 1 w | DCb | 91637 | DC-1 | R13-8M |
| R135 | 12.5 kΩ | 3%, 7 w | WW | 91637 | RLS-1 | R7-12.5K |
| R136 | 22.5 kΩ | 1%, 1/2 w | WW | 11502 | WW8J | R18-10-22.5K |
| R137 | 5 kΩ | 10%, 5 w | WWVar | 71450 | AW | RP3-5K |
| R401 | 100 Ω | 10%, 1/2 w | Comp | 01121 | EB | R1-100 |
| R402 | 470 Ω | 10%, 1/2 w | Comp | 01121 | EB | R1-470 |

(i) Part contained in Model 4102 Input Can.

RESISTORS (Cont'd)

| Circuit Desig. | Value | Rating | Type | Mfg. Code | Mfg. Part No. | Keithley Part No. |
|---|---|---|---|---|---|---|
| R403 | 100 Ω | 10%, 1/2 w | Comp | 01121 | EB | R1-100 |
| R404 | 470 Ω | 10%, 1/2 w | Comp | 01121 | EB | R1-470 |
| R405 | 100 Ω | 10%, 1/2 w | Comp | 01121 | EB | R1-100 |
| R406 | 100 Ω | 10%, 1/2 w | Comp | 01121 | EB | R1-100 |
| R407 | 10 kΩ | 10%, 1/2 w | Comp | 01121 | EBq | R1-10K |
| R408 | 100 kΩ | 10%, 1/2 w | Comp | 01121 | EB | R1-100K |

VACUUM TUBES

| Circuit Desig. | Number | Mfg. Code | Keithley Part No. |
|---|---|---|---|
| V1 (i) | 5886 | 80164 | EV-5886-5P |
| V2 (i) | 5886 | 80164 | EV-5886-5P |
| V3 | 6CB6/7056 | 94154 | EV-6CB6/7056 |
| V4 | 6CB6/7056 | 94154 | EV-6CB6/7056 |
| V5 | 6CM6 | 00011 | EV-6CM6 |
| V6 | OB2 | 86684 | EV-OB2 |
| V7 | OB2 | 86684 | EV-OB2 |

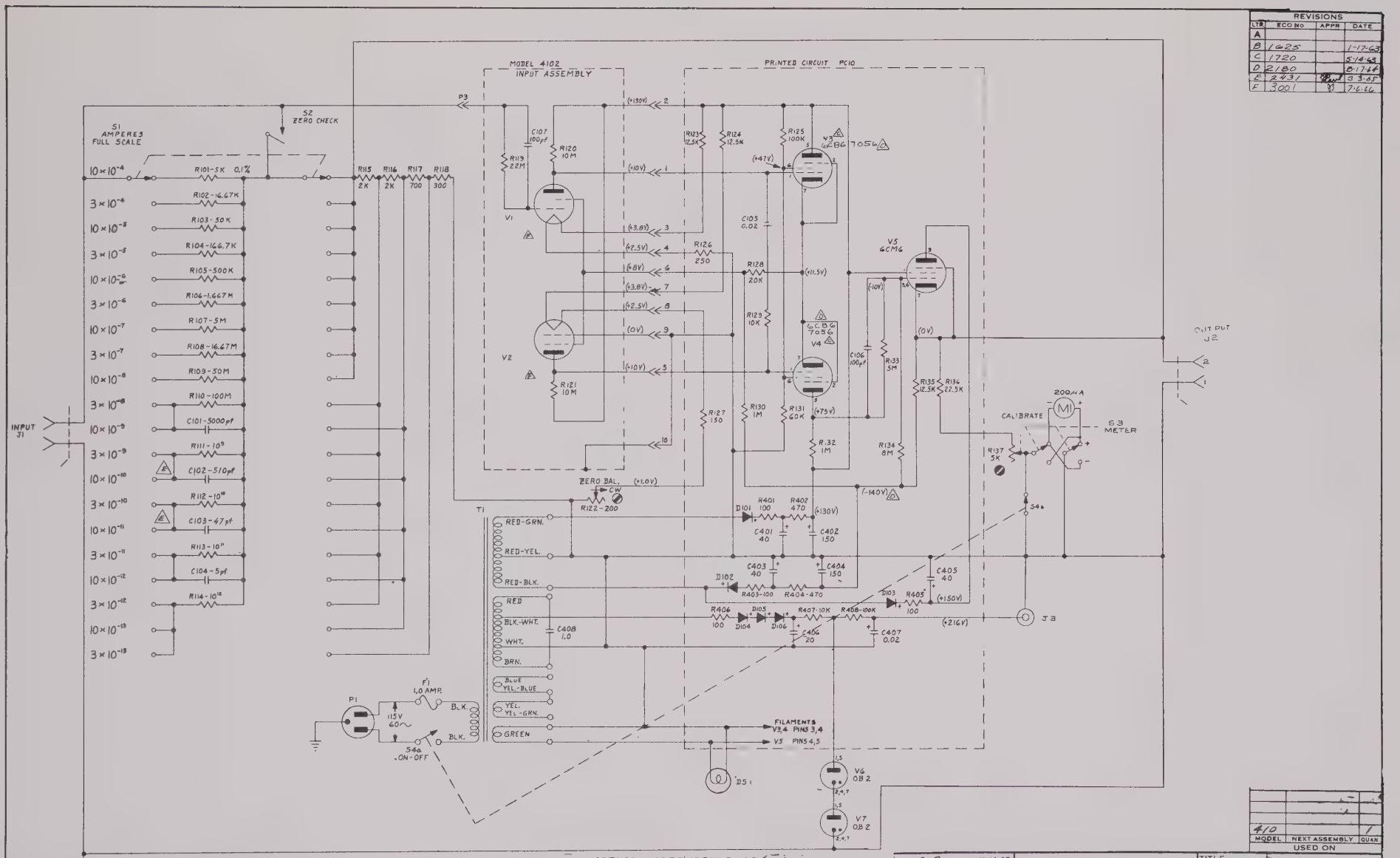
(i) Part contained in Model 4102 Input Can.

| | | | |
|---|---|---|---|
| 00011 | Sylvania Electric Products, Inc. Buffalo Operation of Sylvania Electronic Systems Buffalo, N. Y. | 28520 | Heyman Mfg. Co. Kenilworth, N. J. |
| 01121 | Allen-Bradley Corp. Milwaukee, Wis. | 56289 | Sprague Electric Co. North Adams, Mass. |
| 02660 | Amphenol-Borg Electronics Corp. Broadview, Chicago, Illinois | 63060 | Victoreen Instrument Co. Cleveland, Ohio |
| 08804 | Lamp Metals and Components Department G. E. Co. Cleveland, Ohio | 71450 | CTS Corp. Elkhart, Ind. |
| 11502 | International Resistance Co. Boone, N. C. | 71590 | Centralab Division of Globe-Union Inc. Milwaukee, Wis. |
| 14167 | Efcon, Inc. Garden City, L. I., N. Y. | 72982 | Erie Technological Products, Inc. Erie, Pa. |
| | | 73138 | Helipot Division of Beckman Instruments Inc. Fullerton, Calif. |

TABLE 5 (Sheet 1). Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)

| | | | |
|---|---|---|---|
| 75915 | Littelfuse, Inc.<br>Des Plaines, Ill. | 86684 | Radio Corp. of America<br>Electronic Components and Devices<br>Harrison, N. J. |
| 79727 | Continental-Wirt Electronics Corp.<br>Philadelphia, Pa. | 91637 | Dale Electronics, Inc.<br>Columbus, Nebr. |
| 80164 | Keithley Instruments, Inc.<br>Cleveland, Ohio | 91737 | Gremar Mfg. Co., Inc.<br>Wakefield, Mass. |
| 81483 | International Rectifier Corp.<br>El Segundo, Calif. | 93656 | Electric Cord Co.<br>Caldwell, N. J. |
| 82879 | Royal Electric Corp.<br>Pawtucket, R. I. | 94154 | Tung-Sol Electric, Inc.<br>Newark, N. J. |

TABLE 5 (Sheet 2). Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)




| REVISIONS | | | |
|---|---|---|---|
| LTR. | ECO NO | APPR | DATE |
| A | | | |
| B | 1625 | | 1-17-63 |
| C | 1720 | | 5-14-63 |
| D | 2180 | | 8-17-64 |
| E | 2431 | | 3-3-65 |
| F | 3001 | | 7-6-66 |

NOTES:
1.) VOLTAGES MARKED ( ) MEASURED WITH OUTPUT ZEROED WITH XTYM
2.) ALL RESISTANCE/CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS RESPECTIVELY UNLESS OTHERWISE NOTED
3.) ○ FRONT PANEL CONTROL

◐ FRONT PANEL SCREWDRIVER ADJ. C.W. ROTATION
◑ REAR PANEL SCREWDRIVER ADJ.
◒ INTERNAL SCREWDRIVER ADJ.
★ NOMINAL VALUE ADJUSTED AT FACTORY
K = 1000 OHMS
M = MEGOHMS
pf = PICOFARADS

| | | |
|---|---|---|
| DRN R.R. | DATE 11-11-62 | |
| CKD | DATE | |
| ENG. APPR | DATE | |
| PILOT RELEASE | DATE | |
| PROD RELEASE | DATE 9-8-64 | |

KEITHLEY INSTRUMENTS CLEVELAND OHIO

TITLE SCHEMATIC, MODEL 410 MICRO MICROAMMETER

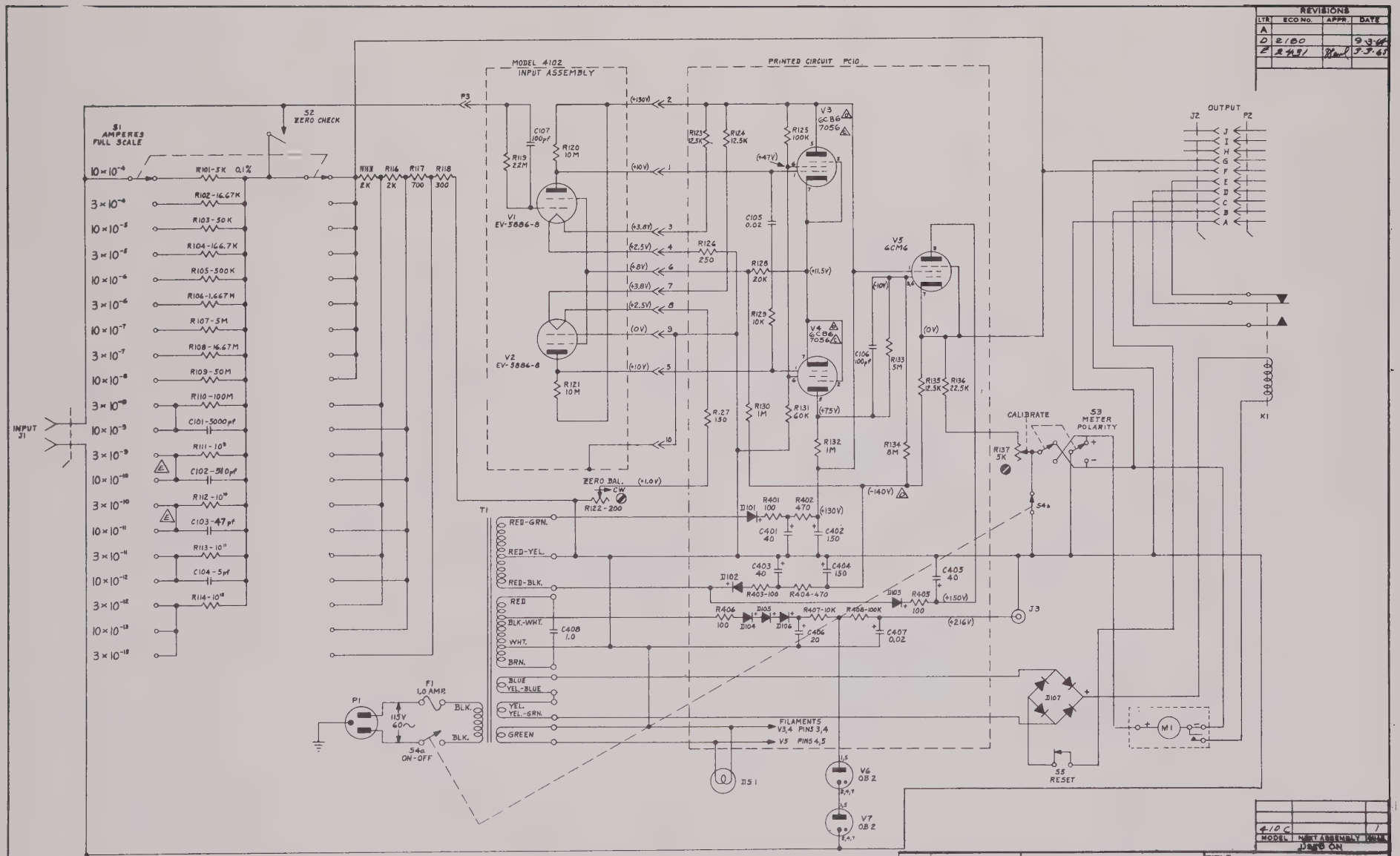
MATERIAL

FINISH

PART NUMBER 10867D

| 410 | 1 |
|---|---|
| MODEL | NEXT ASSEMBLY / QUAN |

USED ON




NOTES:
1) VOLTAGES MARKED ( ) MEASURED WITH OUTPUT ZEROED WITH VTVM
2) ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS RESPECTIVELY UNLESS OTHERWISE NOTED

3) ○ FRONT PANEL CONTROL
◐ FRONT PANEL SCREWDRIVER ADJ.
◑ REAR PANEL SCREWDRIVER ADJ.
◒ INTERNAL SCREWDRIVER ADJ.
✳ NOMINAL VALUE ADJUSTED AT FACTORY

K = 1000 OHMS
M = MEGOHMS
PF = PICOFARADS
↑ = C.W. ROTATION

| | | |
|---|---|---|
| DRN R R | DATE 11-11-62 | KEITHLEY INSTRUMENTS CLEVELAND, OHIO |
| CKD. | DATE | TITLE SCHEMATIC, MODEL 410C MICROMICROAMMETER |
| ENG APPR. | DATE | MATERIAL |
| PILOT RELEASE | DATE | FINISH |
| PROD RELEASE | DATE 9-8-64 | PART NUMBER 11165D |

410C 1
MODEL NEXT ASSEMBLY USED ON

CHANGE NOTICE

July 13, 1966

MODEL 410 MICRO-MICROAMMETER

Page 6-2. Change to the following:

| Circuit Desig. | Value | Rating | Type | Mfg. Code | Mfg. Part No. | Keithley Part No. |
|---|---|---|---|---|---|---|
| C406 | 20 µf | 450 v | ETB | 56289 | TVA1709 | C8-20M |

Page 6-5. Change to the following:

| Circuit Desig. | Number | Mfg. Code | Keithley Part No. |
|---|---|---|---|
| V1 (i) | 5886 | 80164 | EV-5886-5P |
| V2 (i) | 5886 | 80164 | EV-5886-5P |

(i) Part contained in Model 4102 Input Can.

Table 5: designation 02660 should read:

Amphenol - Borg Electronics Corp.
Broadview, Chicago, Illinois

KEITHLEY INSTRUMENTS, INC.
12415 EUCLID AVENUE CLEVELAND, OHIO 44106